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PERMANENT INTERNATIONAL ASSOCIATION
OF
NAVIGATION CONGRESSES

INLAND NAVIGATION

A Study, from an Economical and Technical POINT OF VIEW, OF THE WORKING AND MECHANICAL TRACTION OF BARGES ON RIVERS AND CANALS, AND OF THE BY-LAWS REFERRING THERETO

BY

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NOTE

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The study that follows was prepared by Mr. LAVAUD, Member of the Paris Chamber of Commerce, Sub-Director of the « Société Générale de Touage et de Remorquage », with a view to the XIIIth International Congress which should have taken place at Stockholm in 1915; it was already finished at the end of July 1914.

The long interruption in the work of the Association since that date did not allow of considering, until the present moment, the publication of this interesting study.

In spite of the profound modifications that economical conditions have undergone, especially as regards the prices quoted in the course of the work, we esteem that they may still serve as a useful measure for the installations or operations to which they correspond; that the relative values of statistical particulars put forward by Mr. LAVAUD have not sensibly varied, notably the results of trials pursued for a great number of years by the technical Service of the « Société Générale de Touage et de Remorquage » under the direction of its Engineer, Mr. Avril.

Mr. Lavaud's study is therefore still, we feel convinced, of considerable interest for the Members of the Association to whom we are happy to present, under these conditions, the important and useful work of our Colleague, who has quite recently become a Member of the French Delegation forming part of the Permanent International Commission of Navigation Congresses.

Paris, September 1920.

A STUDY, FROM AN ECONOMICAL AND TECHNICAL POINT OF VIEW, of the Working and Mechanical Traction of Barges on Rivers and Canals, and of the By-laws referring thereto

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The Industry of Transports by water finds itself, by its very nature, in a certain state of inferiority as compared with Railways.

The efforts of all those who are interested therein, Management, Traction Companies, Watermen, should tend towards a double object.

— To quicken the rate of travel of boats, in order to diminish as far as possible, the most serious, one might say the only, inconvenience that this kind of transport presents.

— To reduce, as far as can be done, the expenses of every nature, with the aim of still further increasing the advantages that it offers over other methods : economy.

Now, if from certain points of view these two aims can be attained by the same means, rapidity increasing the utilisation of material and reducing therefore the expenses, from other points they are totally in opposition.

As a matter of fact, at any rate in France, there is generally a difference between the interests of the carrier and the contractor for the traction; the interest of the former is to run a boat carrying, with equal dimensions, the greatest amount possible of goods; on the contrary the latter finds it advantageous to have small units, easier to tow but of smaller tonnage.

There is therefore no unique solution to the problem which must be treated, to a certain extent, according to each particular case.

From now, however, two general classifications may be established according to whether it is a matter of transport by canals, which is characterised by a reduced section and an imperceptible or weak current or of transport by river, of which the section is more or less unlimited, but of which the current is appreciable, even violent sometimes, and variable according to the period of the year.

A. — NAVIGATION ON CANALS.

On canals where the cases of loss of time due to stoppages, crowding at and passing through locks, etc., are numerous, the speed is of less relative importance than on rivers, where these causes of delay arise far less frequently.

In other terms, the quickening up of Canal traffic can only be obtained by an improvement at one and the same time of the towing speed, the rapidity with which boats are passed through the locks, a sound regulation of the traffic and above all a judicious application of same.

On rivers, of which the reaches are longer, and more particularly when the transport is against the current, the traction speed is, on the contrary, the most important factor in the total length of the journey.

Influence of the weight-carrying capacity of the boat on the price of freight.

But there is another element which has at least as much influence as the preceding on the reduction of prices of transport by water, it is the weight-carrying capacity of the boat.

A few figures, better than any considerations, will make the capital rôle that this element plays in the price of freight stand out clearly.

One example : that of a barge carrying a full load of coal of 280 to 290 tons from Pont-à-Vendin, a bank-side of the Lens mines, to Paris.

In France, the classification law of the 5th of August 1879 fixed as follows the dimensions of locks on the principal waterways of the system of Inland Navigation :

Minimum depth	2	meters	(6.56 ft)
Length of lock	38.5	»	(125 ft)
Width of lock	5.2	»	(17 ft)

This law having limited the draught of boats to 1.8 meters (5.9 ft), the Bilander by which, almost exclusively, transports are made on these ways, has an average tonnage of 285 tons.

Now the work on several of the large navigable waterways of the North has been executed with a view to providing for an increased draught of 0.2 meters (7 3/4'') and this improvement could be realised by work the cost of which would not be excessive.

With a draught of 2 m. (6.56 ft), the same barge would carry 40 tons more, thus 325 tons.

This small extra load would bring about quite an appreciable reduction in the price of transport.

In effect, all accessory expenses remaining the same, only those for traction would increase proportionately with the tonnage.

On the canals from Pont-à-Vendin to Paris, that is to say for a distance of 194 km. (120 miles), the increase in the cost of traction for these 40 supplementary tons would not be more than 28 francs.

From Sanville to Paris, on the Oise and the Seine, for a distance of 176 km. (110 miles), the increase in the cost of towing would be very slight and would certainly not reach 12 francs on an average.

That makes a maximum total of 40 francs for a journey of 370 km. (230 miles) for the transport of 40 tons.

Now the freight from Lens to Paris varies, according to the season, from 4.50 francs to 6 francs, or an average of 5.25 francs.

From the simple fact of being able to carry this supplementary load the barge-owner could, without decreasing his profit, accept as price :

$$\frac{285\ \text{T.} \times 5\ \text{fr.}\ 25 + 40\ \text{fr.}}{325\ \text{Tons}} = 4\ \text{fr.}\ 75$$

that is to say a reduction of 0 fr. 50 per ton, representing a rebate of :

$$\frac{5\ \text{fr.}\ 25 - 4\ \text{fr.}\ 75}{5\ \text{fr.}\ 25} = 10\ \%\ \text{about.}$$

This simple calculation demonstrates the importance that must be attributed to the increase in the tonnage of boats.

One cannot help regretting that, in France, the Administration has not pursued a programme of improvement of the principal navigable waterways, the object being to render them accessible to boats of a much greater tonnage than that of the barge, 400 to 500 ton boats or even more.

If, entering into this way, it had provided for, at the time when the locks on the St-Quentin Canal were doubled, works through which boats of this tonnage could pass; if the locks of the « Canal du Nord », which are being built, had been planned with the same idea, it would be possible to conceive, in the near future, the realisation of an artery of large section joining up the centres of production to the great centre of consumption, Paris.

Thus it would be enough to increase the carrying capacity of a boat by 14 % (from 285 to 325 tons) to see the freight diminish by 10 %.

The increase of tonnage is therefore, without the least doubt, the solution of the question of low priced transport.

The influence, on the cost of freight, of the rate of travelling.

Unfortunately the future is provided for and a perceptible increase in the tonnage of boats is no longer to be considered except for new routes to be created and which will be independent of the existing ones.

The development of the speed having for object the efficiency of the boat is therefore, to-day, the sole aim towards which all efforts should tend.

The following table gives the conditions for a journey of a barge from Pont-à-Vendin to Paris.

STAGE	Route taken	Distance	Means of traction	Price loaded	Price empty on return	Number of locks	Average length of journey
		Kil.		Francs	Francs		Days
Pont-à-Vendin-Douai Courchelettes-Bassin-Rond	Deule Scarpe and Sensée Canals	54	Electric and Horse	53.85	18.15	5	5
Bassin-Rond-Cambrai	Escaut canalised	12	Horse	16.30	4.05	5	2
Cambrai-Le Bosquet	St-Quentin Canal	25	do.	26.00	8.55	17	3
Le Bosquet-Lesdins	do.	20	Towing	11.40	—	1	1
Lesdins-Chauny	do.	48	Horse	41.70	16.40	17	4
Chauny-Janville	Lateral canal to the Oise	35	do.	290	140	4	2
Janville-Conflans	Oise	105	By tug	to	to	7	2
Conflans-Paris	Seine	71	do. Towing	120	80	2	2
		370		439.25 to 269.25	187.15 to 127.15	58	21

The Journey lasts about 20 days, but if we add the time lost, by reason of crowding in one place, waiting for horses in another ; at St-Denis for the final destination ; in winter owing to ice or floods, etc., we finally find that the journey cannot be completed in less thave 25 days to go and as many to return.

The present practice of the consignee lays up the boat for about a fortnight for unloading.

On his return the barge-owner very frequently loses 30 or 40 days looking for a cargo, going to the place of shipment, waiting for his cargo, etc.

Briefly the return journey requires in all generally 90 days and the barge only makes 4 journeys per year between Lens and Paris.

It is certain that an improvement in the means of traction, less from a point of view of absolute speed than from that of a decrease in the time lost in waits, in loading and unloading, would be of a nature to reduce the time of the journey and to permit the accomplishment of a supplementary journey.

In this case what would be the corresponding reduction in the cost of freight.

The expenses of a journey from Lens to Paris and back are as follows.

		SUMMER	WINTER
		Francs	Francs
Freighting commission		60.00	60.00
Interest on advances.		10.00	10.00
Traction expenses, loaded .	preceeding table	269.25	439.25
Traction expenses, empty .		127.15	187.15
Food and salary of pilot		77.00	77.00
Incidental expenses		36.60	36.60
		580.00	810.00

With 4 journeys a year the average price of freight is, as we have seen, 5 fr. 25.

If the barge makes one more, the expenses will be increased by $\frac{580\text{ fr.} + 810\text{ fr.}}{2} = 695\text{ fr}$ and the tonnage carried annually will be raised to 285 t × 5 = 1425 tons.

So that the barge-owner could accept, without reducing his profit, as price :

$$\frac{285\text{ T.} \times 4 \times 5\text{ fr. }25 + 695\text{ fr.}}{1425\text{ T.}} = 4\text{ fr. }70$$

But it must be borne in mind that no account is taken here of the extra wear and tear to the barge and to gear, nor of the extra work that a supplementary journey would entail.

So that an increase of 25 % in the output of the barge, due to speeding up, has less influence on the freight than an increase of 14 % in her carrying capacity.

Increase in the travelling speed of boats.

A barge takes at least 25 days to travel over the 350 kilometers between Lens and Paris, and one can, taking into consideration the differences that exist between navigation on canals and on rivers, divide this journey into two stages :

One of 20 days, employed in passing through 49 locks and travelling over the 194 km. of canals between Pont-à-Vendin and Janville, the other of 5 days employed in passing through 9 locks and travelling the 170 km. of river between Janville and Paris.

The first part of the journey is therefore made at an average rate of 9.7 km. per day, and the other at 35 km.

Now the hauling speed, even with horses, reaches 2 km. an hour, the journey of 9.7 km. per day therefore only corresponds to less than 5 hours of effective travelling.

The rest of the day is absorbed by losses of time of all sorts, which it is most important to reduce, and of which the principal causes are :

Crowding at the locks by reason of the time it takes to pass through.

Obstruction in the reaches or in the docks, resulting either from insufficiency of traction, or, more often, from defective organisation of traction, from a want homogeneity and unity of direction.

It must also be admitted that the congestion in the reaches is often caused by a regretable laxness of necessary discipline.

The barge-owner refuses to advance for some motive or other, or perhaps without any motive, opposes, by force if needs be, the passing before him of his competitors and thus stops, during many hours sometimes, the whole of a public service.

Form to be given to locks to quicken up the passing through of same.

The crowding at locks can be lessened by their arrangement and by the mechanical means employed for accelerating the manœuvring of the boats, the gates and the sluices.

In this respect, it does not seem possible to improve on what has been accomplished at the Gœulzin Lock which may be considered, actually, as a veritable model one.

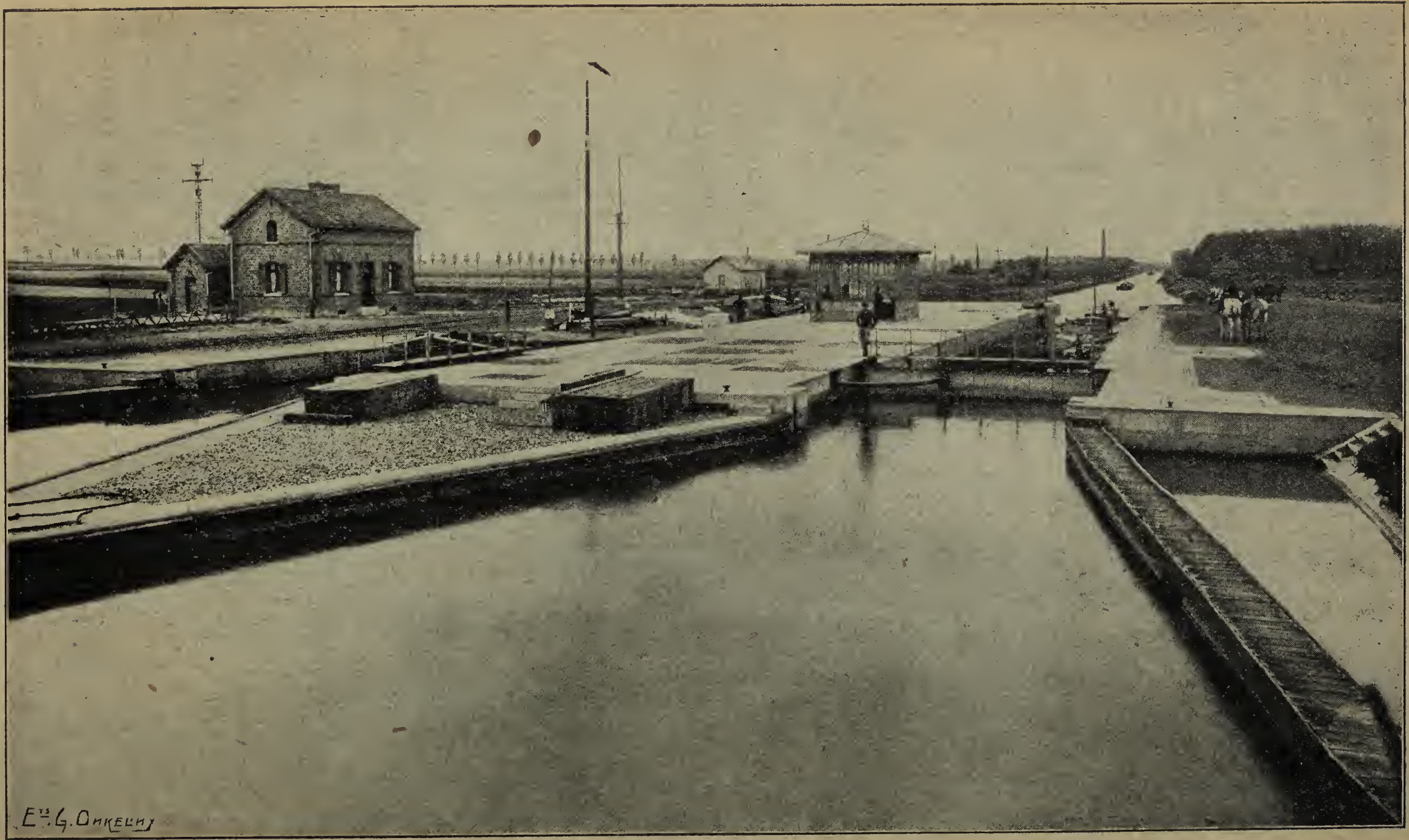

Fig. 1. — Gœulzin Lock, on the canal of the Sensée.

Gœulzin Lock

This is situated on the canal of the Sensée, 4 km from the junction of this river with the Scarpe. Fig. 1 gives a photographie view of it.

It compensates for a fall of 4 m. 90. (16 ft). (Fig. 2.)

The lock is double, and the width of the chambers, 6 m. (19.7 ft) facilitates the entrance of the barges.

The approach is wide enough to allow of a boat, which is about to enter, approaching quite near to the gates without hampering the exit of the one that has just been locked.

The chamber thus remains unoccupied for as short a time as possible.

The movements of the boats are performed by « electric horses » (or tricycles) and are executed with the greatest rapidity. Aquaducts, liberally calculated, and fed by numerous inlets, distributed all along the chamber, accelerate as much as possible, the filling and emptying.

The working of the gates and sluices is performed electrically from a cabin placed in the centre of the approach.

The whole of the electrical part was studied and carried out by Messrs Hillairet and Huguet, of Paris.

Much ingenuity is to be found in the details, and that perfection in the conception and execution which characterizes the work of this firm whose high reputation has been legitimately earned. This plant does it the greatest honour.

Here is a short description:

Generating Station. — This contains a 110 volt continuous current dynamo of 7.5 kw, type IV bis MD with a vertical shaft, driven directly by a hydraulic turbine making 400 revolutions. (Fig. 3).

The switch-board of white marble on a metal framework with pitchpine framing includes :

A doube-pole two-way switch, an aperiodic voltmeter and ammeter, two fusible cut-outs, and an exciting rheostat.

The starting apparatus for each of the motors for the gates and sluices is composed of a double-pole two-way switch, for

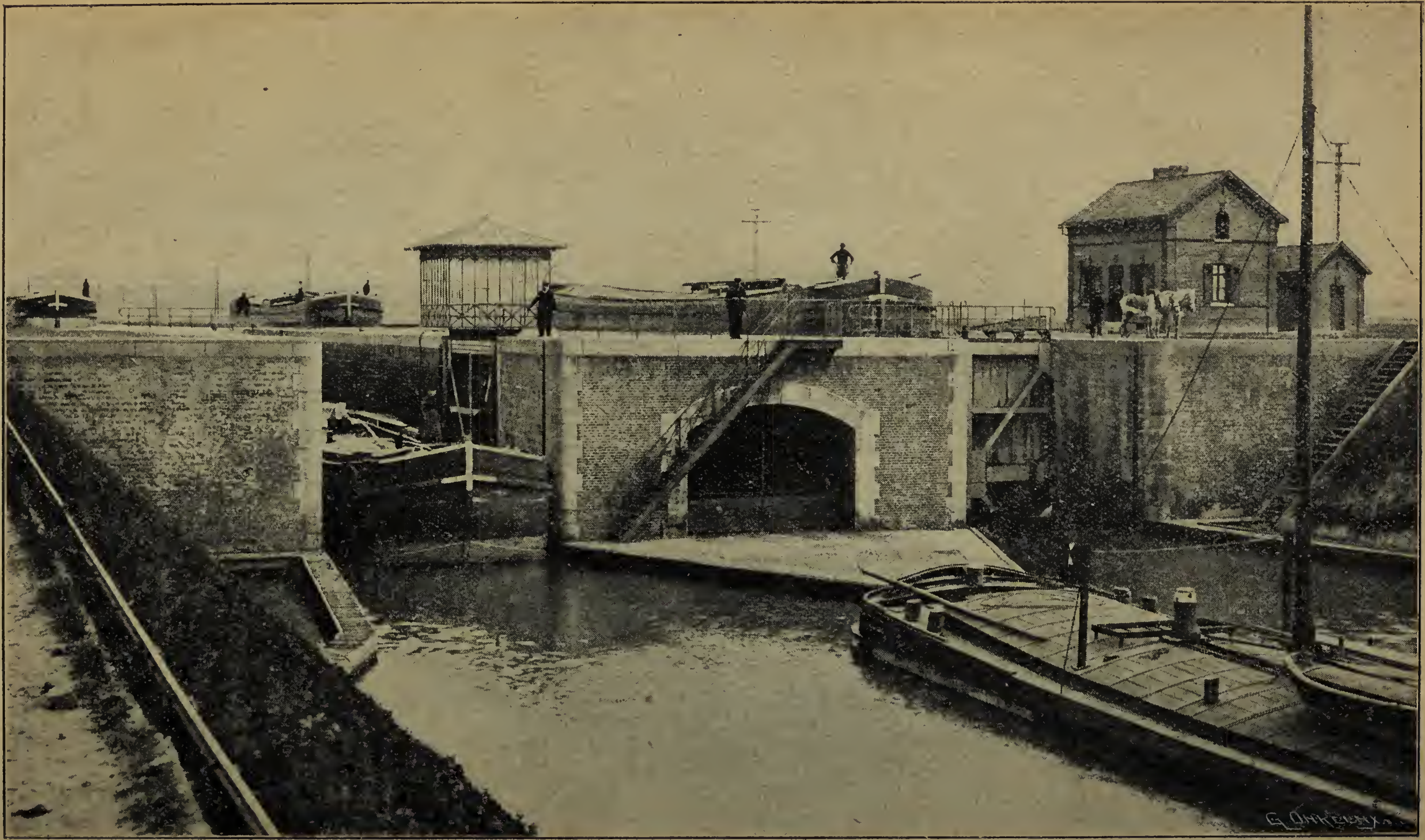

Fig. 2. — Gœulzin Lock, on the canal of the Semsée.

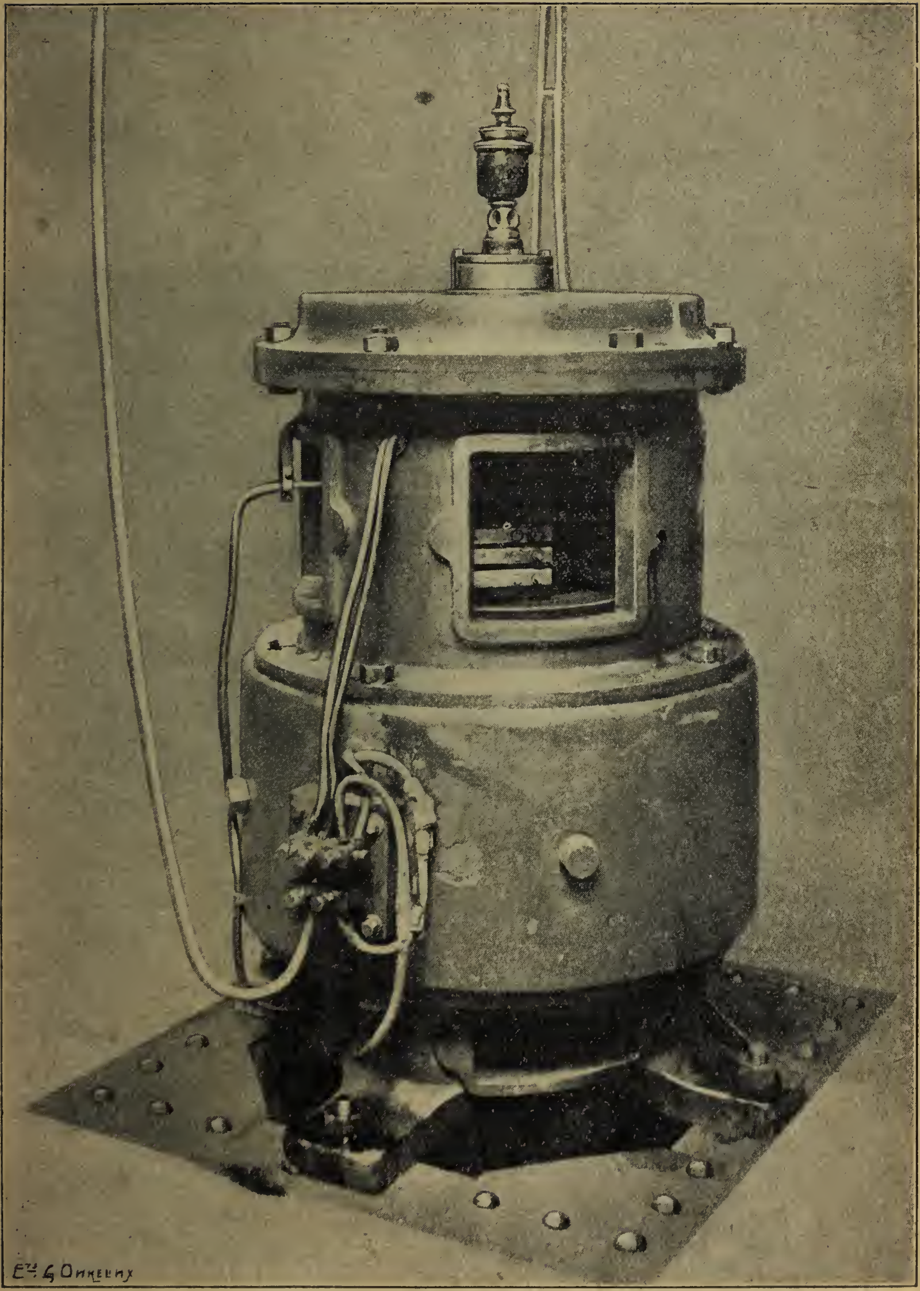

Fig. 3. — Hydraulic turbine.

running in two directions, and of a starting rheostat with an overload cut-out.

The control of the gates. — Each of the four gates is worked by an enclosed motor, type II bis MD which absorbs, when working, about 1.5 kw. at 500 revolutions. (Fig. 4).

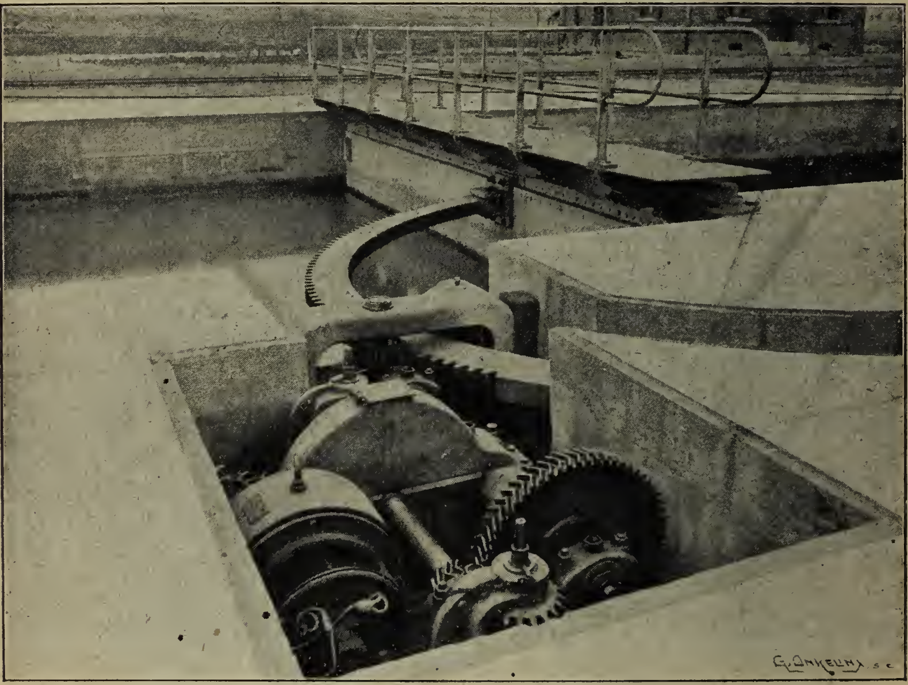

Fig. 4. — Electrical control of the gates of Gœulzin Lock.

The manœuvre lasts on an average 75 seconds.

The starting of each motor is performed from a distance by a corresponding reversing starting rheostat. The stopping is produced automatically by the action of the maximum cut-out which cuts off the current when the gate reaches its limit position, as well for the opening as for the shutting.

The control of the sluices. — Each of the ten sluices is worked by an enclosed motor, type 1 bis MD which absorbs, when working, about 900 watts at 850 revolutions (Fig. 5).

The manœuvre lasts on an average from 25 to 30 seconds.

The starting of each motor is performed from a distance, by means of a corresponding reversing starting rheostat. The stopping is produced automatically by the action of the maximum cut-out which cuts of the current when the sluice-gate reaches the limit positions, as well for the opening as for the shutting.

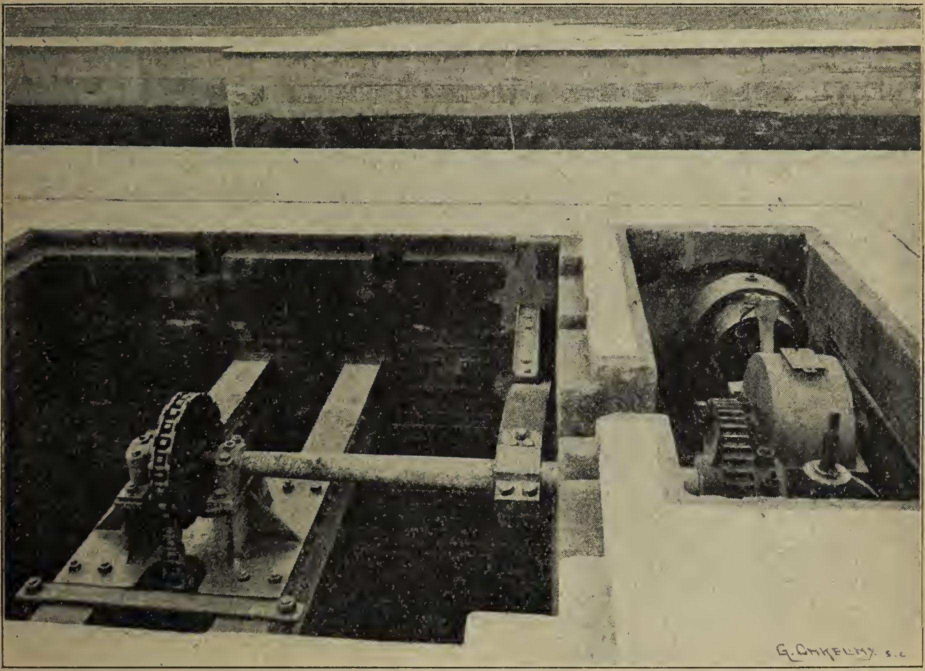

Fig. 5. — Electrical control of the sluices of Gœulzin in dock.

The line. — The wires joining up the different electrical apparatuses are placed in channels, they are naked and supported by glass insulators.

Results obtained.

On the canal lateral to the Oise of which the locks, although modern, are far from offering all the improvements found at Gœulzin, the time strictly necessary to pass a barge through is 17 minutes.

It is only by means of great activity, on which one cannot always count, both on the part of the barge-owner and on that of the lock-keeper, that it is possible to pass 4 boats in an hour (2 mounting and 2 descending), and this figure must be taken as a maximum one.

If, by reason of lack of boats going in the two directions, one is obliged to work with false lockfulls, the number of boats that can be passed through in one hour is reduced to 3.

Now at Gœulzin five boats per hour are easily locked.

This is quite an appreciable gain, amounting to 25 %.

But the fall is nearly 5 m. (16 ft) and the gain would be much more important if a comparison were made with a lock of an equal fall not possessing the improvements of this remarkable work.

Increase in the height of the fall of locks.

If it is a question of constructing a canal or if the topography permits of it, in the case of an existing waterway to be improved, the increase of the height of the fall is always to be recommended, this with a view to diminishing the time lost in locking.

In this way the lock at Gœulzin has replaced two old locks.

The fall can be, without excessive cost, carried to almost any height, and may reach 20 m. (65 ft), thanks to the remarkable device studied by Mr. Jacquinot, the eminent Engineer in Chief of Roads and Bridges on the special service of navigation between Belgium and Paris.

A work of this type was presented by the « Société des Grands Travaux » of Marseilles, at the competition for the amelioration of navigation on the Rhone, in 1911, and obtained a second prize of 12,000 francs.

The chamber is formed of a compartment of reinforced concrete. Metal ribs constitute the frame-work of it. The heads are united in the cross girders supporting the working foot-bridge and the feet fitted into the masonry-work of the apron.

In this way the lateral-walls are made with cross-pieces and resist, under the best conditions, the stresses which are produced alternately, towards the exterior, when the chamber is full, and towards the interior, when it is empty.

The economy basins are placed in the lateral walls, they are fairly numcrous and installed one above the other like the drawers in a chest of drawers.

Besides this general principle of construction, this type of work presents a large number of highly ingenious devices, well thought out, and which do the greatest honour to their author Mr. Jacquinot, Engineer in Chief.

The form of the present paper unfortunately does not allow of describing them all.

We will limit ourselves to speaking of a few :

Two groups of sluice-gates, placed in the middle of the long wall, have taken the place of the four groups usually placed at the angles of the chamber, and one of these groups is enough for the working, the other only being provided to act in case of any accident to the first group.

The result of this is an appreciable economy and a considerable simplification of the working.

These sluice-gates are called « taps »; they are double, in perfect equilibrium and their safe and sure working leaves nothing to be desired. They are provided with a special device, which is applied also to the gates, and which gives perfect watertightness.

The type which was worked out for the Rhone competition was for a fall of 12 m. (39 ft) and had six economy basins.

The quantity of water required to supply a lockful is the same as that for a lock with a fall of only 2.64 m. (8.7 ft).

This is a still further and acceptable advantage for canals of which the feeding is difficult.

Increase of the hauling-speed.

The obstruction in the reaches is incontestably the most important cause of loss of time.

This obstruction, in our opinion, will be decreased less by an increase in the hauling-speed than by a sound organisation of the traction, with perfect unity of direction and complete homogenity in the mode of traction.

An increase in the real speed of the boat would certainly constitute an appreciable improvement, but this could only be obtained by means of exaggerated expenses entirely out of proportion to the result sought after, or else by reducing the size of the barge, and this would be going directly in opposition to the goal to be reached, the reduction of freight.

The weight carried plays, indeed, as we have seen a preponderant role in the lowering of the price of transport.

The speed of hauling by horses is at the outside 2.5 km. (1.56 miles) per hour. To increase this to 4 km. (2.5 miles) for instance, (admitting, as established by Mr de Mas, Inspector General, that the effort varies as the power 2.25 of the speed), the resistance to progress would be increased in the ratio of $\left(\frac{4}{2.5}\right)^{2\ 25}$ 2.88, that is to say it would be tripled, or nearly so.

The effective time during which progress is made is certainly inferior to 5 hours per day, we see then what would be the cost price of these few extra kilometers, the total of which would hardly reach 5 h. × 1.5 km. = 7.5 km. (4.7 miles) per day.

Towing by horses

At the present time this method of hauling is certainly the most economical.

On certain sections of the great waterway Nord-Paris, the prices charged by the contractors, prices which allowed them to realise a profit (a very small one probably), were until quite recently, 0,0028 frs per kilometric ton, thus for a barge carrying 285 tons, 0.80 fr. per kilometer per barge.

But by reason of the ever-increasing difficulties that these contractors meet in finding a staff, a staff whose demands increase in inverse ratio to the work and the care taken of the horses, the necessity of having recourse to mechanical means makes itself more and more imperiously felt.

Electrical towing.

At the head of these means must be placed electrical traction on rails which, along the waterways of the North of France and thanks to the persistent efforts of the « Société de Halage Electrique de Douai » and its eminent director, Mr. Chanay, has nearly reached the acme of perfection.

After the remarkable reports which have been presented, notably by Mr. Larivière, Engineer in Chief of Roads and Bridges and by Mr. du Bosquet, Managing Director of the above mentioned Company, the subject is exhausted.

It will be enough, if we recall to mind, that the towing is effected by means of locomotives running on a single track laid on the bank of the canal.

Some recent improvements have been made in these machines.

The first ones had a total weight of 9 1/2 tons, of which 3 1/2 tons was added ballast; the bodies were made of sheet-iron and beams and weighed 2 1/2 tons.

In order to avoid the movable ballast, the frames are actually made of cast-iron and weigh about 6 tons.

The total weight of the new machines is thus from 10 to 10 1/3 tons.

The number of starting contacts has been raised to 7, and the band resistances, corresponding to the last contacts, have been replaced by bars of special cast-iron.

Each tractor tows two barges, and when two locomotives meet on the single track they simply change their barges and go back again.

This manœuvre only requires a few seconds to perform and does not present the least inconvenience.

The working of the traction on rails extends over a length of 60 km. (37 1//2 miles), along the canals of the Deule, the Scarpe and the Sensée.

Besides this the Company works, as far as Bethune, a portion of 23 km. (14 1/2 miles) of the Canal of the Aire by means of tricycles (or electric horses) on the banks.

These latter are also used for the manœuvring of barges in and out of the locks and in the vicinity of same.

Progress that may be expected from the use of Electrical Traction.

In spite of all the efforts made and of the technical improvements realised, it must be admitted that the speed of the boats has not sensibly increased, and that the prices are about the same as elsewhere.

But could it be otherwise with the method of working that is adopted?

The company owning the concession has not a monopoly and an appreciable part of the towing is performed by horses.

It follows therefore that the speed of the barges, towed mechanically, is limited by the speed of the barges towed by horses, crossings being as a matter of fact impossible owing to the crowding, to the lack of good will that the barge-owner shows as regards being passed and even, which is curious, the very slight eagerness of one barge-owner to pass another.

The competion between the two methods of traction has not resulted in that lowering of the price which ons might have legitimately expected.

The « Société de Halage » being obliged, before everything else, to redeem the considerable capital sunk, could not think of lowering the tariff, unless it was certain of the whole of the traffic, and it is enough for the horse owner to apply a slightly lower tariff in order to secure work for his beasts.

It is a vicious circle from which it will only be possible to emerge by having recourse to a monopoly.

But it makes a difference if this monopoly is given to a private enterprise or to the State.

The latter has proved itself to be, on many occasions, an indifferent trader, and it ought to limit itself to playing the part of a controller in juxtaposition to a private company which offers every guarantee.

Armed with well studied specifications it could insist on the lowering of tariffs with the increase of traffic, a thing that it would not perhaps consent to do were it both judge and contracting party.

The disappearance of animal traction will allow of, quite naturally, an increase of the towing speed, of mechanically drawn boats, to 3 km. (1 7/8 miles) per hour and their travelling in series of 3 units.

Up to the present time the number is limited to two, and all efforts with a view to increasing it have failed, owing to the formal opposition of the barge-owners, who give their preference to individual towing.

The principal objections that they oppose to towing by convoys are of two kinds :

The exaggerated strain on the mast when it must support the effort imposed by hauling more than one boat and the difficulty that is found in steering the last boat of the convoy.

But it is not difficult to remore the first objection and there appear to be no grounds for the second.

These improvements would have as a result an appreciable economy in the cost of traction and a corresponding diminution in the prices of towing.

These prices, which are actually, per kilometric ton, 0.0035 fr. when going up and 0.003 fr. when coming down, could most certainly, with the heavy traffic on these lines, be lowered to 0.003 fr. and 0.0025 fr. respectively, that is to say they would hardly be equal to the exceptionally low prices quoted higher.

To terminate let us recall that the price of this installation is about 30,000 francs per kilometer, not including the generating stations and the lines for carrying current.

The annual working expenses of a tractor may be put down at :

General Expenses	Fr.	520.00
Current Consumption	»	3,120.00
Driver	»	2,275.00
Upkeep	»	585.00
	Fr.	6,500.00

Towing by automobile tractors.

The canals of the Deule and of the Sensée, with their effective tonnages of nearly 7 million tons for the former and more than 5 million tons for the latter need such costly installations, which however the small tonnage of certain other waterways in no ways justifies.

Such is the case for the Bourgogne canal (effective tonnage 626,199 tons, average 214,759 tons only).

Its great length (242 km. = 150 miles) however renders working by animal traction difficult.

Since 1906, the powerful « Compagnie Générale de Navigation », which deals with the greater part of the traffic, took in hand the matter of instituting mechanical towing by means of a petrol tractor.

Helped by the advice of Mr. Galliot, at that time Chief Engineer of the Canal, a machine was made of which the trials were satisfactory.

But the making of heavy machines was then in its infancy, and submitted to extremely hard work, the tractor had very quickly to be amended.

The Company however took up the question again in 1912 and went, for the construction of a second machine, to Messrs Schneider & C°, whose automobile department, under the skilful direction of Mr. Brillie, has made a speciality of the building of heavy vehicles.

A new tractor was designed, tried and put into service.

Hereafter will be found a few summary particulars concerning this interesting machine.

The chassis which is made of U irons of 100 m/m (4 ins), is joined to the axles by springs, the rear ones being strengthened as they serve also for the driving.

The principal characteristics are :

Wheel-base	1 m. 900	(6.23 ft)
Total length of chassis	3 m. 350	(11 ft)
Total width of chassis	1 m. 470	(4.82 ft)

The wheels are made of wood with metal tyres.

The rear wheels are 200 m/m (8 ins) wide and are ribbed in order to avoid slipping.

There is a 2 cylinder motor with 90 m/m bore and 180 m/m stroke. Two pistons run in each cylinder, according to the well-known disposition of Mr. Brillie.

It develops 12 HP. at 900 revolutions and 14 at 1,200 revs., a speed that can be attained without any inconvenience.

A very exact centrifugal regulator acts on the suction valve for carburated gas and limits the number of revolutions to the driver's will without, however, possibility for this number to exceed 1200.

The carburettor, Schneider system, allows, by means of a simple setting, the indifferent use of petrol or of benzol.

The water circulation is provided for, by means of a thermo-syphon, through a radiator cooled by a ventilator of ample dimensions by reason of the slow speed of running.

The reversed cone starting-gear, is supplied with a special composition, « Ferrodo », which supports high temperatures without inconvenience and allows of slipping during more than one minute at the time of starting.

The speed changing gear allows of realising the following speeds :

1st speed, starting . .	2 km.	(1 1/4 miles)	per	hour.
2nd speed, towing . .	4 km.	(2 1/2 »)	»	»
3rd speed	13.5 km.	(8.4 »)	»	»
Backwards.	5 km.	(3 1/8 »)	»	»

These speeds can be increased by 30 % by making the motor turn at 1,200 revs.

The transmission from the differential to the rear wheels is realised by shafts bearing at their extremity a pinion engaging internally in a crown of which the exterior surface constitutes the drums of the brakes.

A towing hook is jointed to a crossbeam placed behind the driver's seat.

The weight of the tractor in running order with 60 litres (13 1/3 gallons) of carburant in the reservoir, is 1 4/5 tons, of which 1 1/5 tons on the rear axle and 3/5 of a ton on the front.

The trials made on the Bourgogne Canal between Laroche and St Jean-de-Losne (242 km. 151 miles), have given complete satisfaction.

The machine does not manifest the least tendency to overturning.

After 10 months of uninterrupted running, there was no play in the different organs.

The starting, with a few precautions, is made correctly and is obtained in less than 3 minutes with a loaded barge.

The effort is at first 450 kg. (990 lbs) and then diminishes to 300 kg. (660 lbs) for a speed of 3 km. 600 (2 1/4 miles) per hour for a barge with a load of 250 tons.

This machine is too recent for it to be possible to give an exact cost-price for the traction.

The working expenses per barge-kilometer are as follows :

Benzol	Fr.	0.35
Oil	»	0.05
Upkeep	»	0.10
Driver	»	0.30
	Fr.	0.80

This figure does not include either amortization or general expenses.

In any case a towing price in every way comparable with animal traction can be reckoned on, and this with a speed that is considerably greater.

This tractor, which does not need any of the costly installations that electrical towing necessitates, is called upon to render great services for the waterways with a middling traffic where towing by horses becomes every day more insufficient.

Cable-railway towing.

Two recent installations on the canal from the Marne to the Rhine, allow of appreciating the services that may be looked for from this mode of traction.

On many occasions, since a number of years, applications of this system have been tried, however without much success, because electricity alone, with its possibility of dividing up, without excessive expenses and almost without supervision, the motive force in a number of points could allow it to develop its full value.

The two above-mentioned installations are due to the « Compagnie Générale Electrique » of Nancy; here is rapid description of them :

Description of the System.

The bank of the canal to be served is divided up into sections of about 500 m. (550 yds).

At the commencement of each of these an electric capstan works an endless metal cable which, at the other end, passes over a return pulley with a screw stretcher to take up the slack, and supplied with an arrangement for greasing the cable.

In the neighbourhood of the capstan is placed, on the slack half, another stretcher the weight of which moves in a chimney forming a dashpot and destined to soften the violent oscillations.

There is between each of these sections a free space, which may extend to 50 metres (55 yds), which is traversed by the barge by means of the speed acquired.

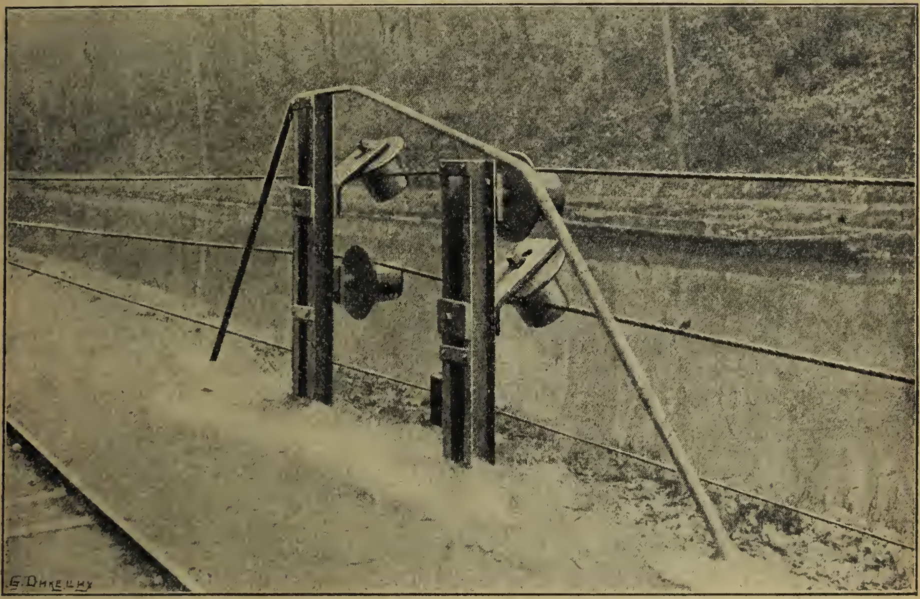

Fig. 6. — Group of supports on a straight bank.

The capstan is set in movement or stopped by two switches placed at the extremities of the section and also by other intermediary switches placed at intervals to any number desired.

Each capstan is worked, through several sets of cog-wheels, by an asynchronous three-phase 10 HP. motor.

The armature is in short-circuit so that the machine can be set going by the simple closing of one of the switches.

The motor is strong and thanks to a special combination it possesses a powerful starting torque and an automatic acceleration of the speed.

As a matter of fact a loaded barge quickly arrives at its travelling speed.

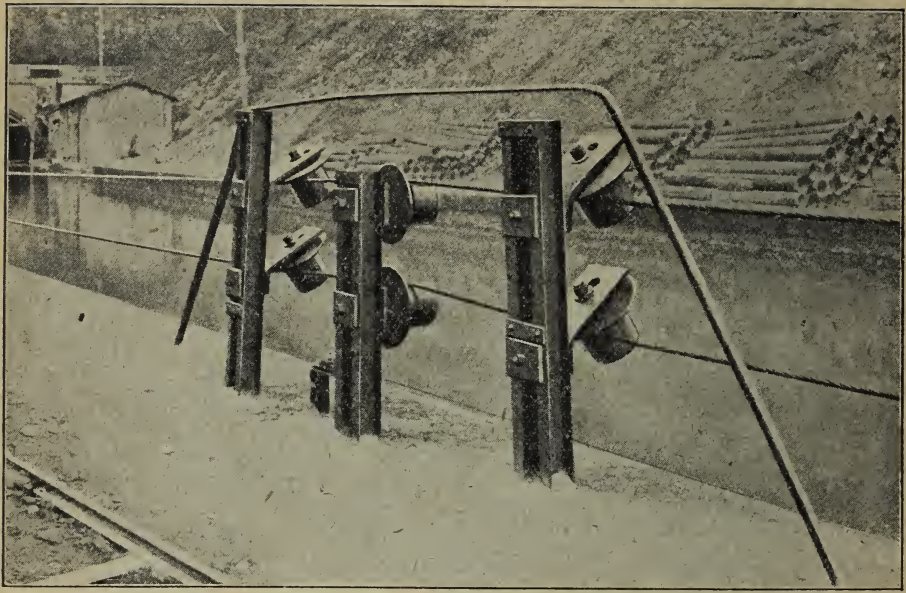

Fig. 7. — Group of supports on a cuwed concave bank.

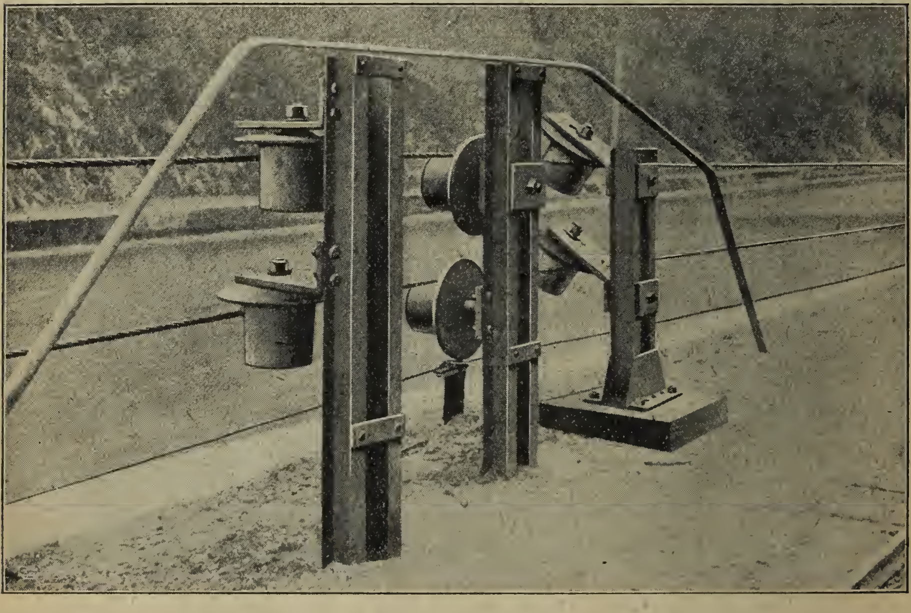

Fig. 8. — Group of supports on a slightly convex bank.

The high-tension of the distributing line is reduced to 190 volts, in the transforming posts, with static transformers, divided up so that one post feeds two capstans.

At about every 40 m. (44 yds), and at all other points where it is necessary, the two halves of the cable are supported and guided by pulleys, the planning and installation of which called for special care, for they must satisfy two conditions that it is difficult to reconcile : Maintain the cable in place and at the same time allow the tow-rope to pass easily. Figs. 6 and 7 show better than any description how the problem has been solved.

The attaching of the tow-rope also presented certain difficulties, for it was necessary to avoid its rolling up round the cable, through the inevitable boring of the latter.

To this end every 25 metres (28 yds) or thereabouts, the cable is enlarged by a solid binding on which a mass of steel balls and bronze rings, threaded to the cable, come to bear.

On the other hand the tow-rope terminates in a kind of grip which is attached to the cable and which is carried along by the above-mentioned balls.

Thanks to the balls and the rings, which turn on each other, the boring does not communicate itself to the tow-rope.

The whole installation composed of, as we have seen, a number of well thought out devices does honour to the « Compagnie Générale Electrique » of Nancy who planned and carried it out.

After this explanation the method of towing the barges is quite easy to understand.

One of the halves is used for towing in one direction the other in the opposite.

The man who accompanies the barge all the time engages the grip on the cable and sets the capstan in motion.

The starting is easily effected and in a few instants the boat has reached its travelling speed of 3 km. (1 1/8 miles) per hour

At the end of the section the same man interrupts the current, unhooks the towrope and the boat continuing its way reaches the next section when the same manœuvre is repeated.

The capstans being designed for towing only one barge at a time, the interval between two barges going in the same direction must be at least equal to the length of a section (500 m. (550 yds) in the case in question) or of two sections (1,000 m.), if, between two barges going up-stream, one going down is introduced, the latter would be towed by the other half of the cable.

From this it results that, at a speed of 3 km. per hour, such an installation, divided into sections of 500 m., can theoretically deal with the towing of 72 barges per day of 12 hours.

To raise this number to 108 barges, it would be enough to reduce the length of the sections to 333 m.

Existing Installations.

The first, as regards the date, is the one that was made in the neighbourhood of the Mauvage tunnel (Canal from the Marne to the Rhine), for carrying materials destined for the repairs of the said tunnel and for clearing out the rubbish.

It works to the complete satisfaction of the contractors, Messrs Fougerolle Frères.

Though it is rather outside the sphere of the present paper, it is not possible to speak of this installation without devoting a few lines to the important works for which it was made.

It was a matter of completely repairing the arch and the uprights and the placing of a floor in this tunnel, the length of which is nearly 5 km. (3 1/8 miles), and this without totally interrupting the navigation, which remained free during the night.

The almost insurmountable difficulties were overcome by a method of unusual elegance and of sure application thanks to the well known contractors Messrs Fougerolle Frères.

Their world-wide reputation has been justified once more, by the scientific manner in which they solved the problem that had been laid before them and by the sure manner in which they pursued this difficult work.

The second installation is that at the entrances to the Foug tunnel on the same canal.

It is laid out over a distance of about 5 km. (3 1/8 miles), from Pagny-sur-Meuse Station to and including lock 15.

It includes locks 14 and 15.

The sections, 10 in number, vary in length from 200 m. (220 yds) to 530 m. (580 yds).

The barges are, in most of the sections, towed individually at a speed of 3 km. (1 7/8 miles) per hour.

In the sections, comprising the tunnel (length 867 m. = 950 yds) and the neighbouring cuttings, the towing is performed, alternatively in one sense and then in the other, 3 or 4 barges at a time, at a speed of about 3 km.

The journey of 5 km., including three locks and a tunnel, and a loss of time of about 30 minutes to get the convoy of barges together, is 2 h. 55 m., thus a commercial speed of 1 km. 7 (1 1/13 miles) per hour.

Towing charges and expenses for the installation.

For a barge with a load of 285 tons, which has been taken up to now as a type, the charge is :

Loaded	Fr.	5.00
Empty	»	2.00

Thus for the journey of 5 km., respectively 1 fr. and 0.40 fr., per boat kilometer, or per kilometric ton fr. 0.0035.

These prices are identical with those of the « Société de Halage Electrique », on the northern canals.

The cost of the installation, including the endless cables, the capstans and guiding pulleys, the high and low tension electric lines and the transforming stations, comes out at fr. 101,000, that is to say fr. 20,000 per kilometer.

The working expenses are reckoned as follows :

Staff	Fr.	14,500.00
Upkeep	»	11,000.00
Current	»	12,000.00
	Fr.	37,500.00

With the actual traffic the above fees should cover very largely the working expenses.

This method of towing is certainly susceptible of rendering, in many circumstances, precious services to navigation, especially on canals (and this is the case for the canal from the Marne to the Rhine) where the locks are exceptionally numerous.

The necessary dividing up then corresponds naturally to the sectionning of the water-way.

It also posseses the advantage of being utilizable, at night for instance, without the presence of any technical staff and of only consuming energy just during the time that it is doing useful work.

Towing by tugs on canals.

If the reaches are exceptionally short, cable towing, by reason of its compulsory sectionning, may render appreciable services.

If, on the other hand, the reaches are long, and the deep section wide enough, it seems that one can, with great advantage, have recourse to an economical but little used method of traction, why it is difficult to say, viz towing by tugs.

On this subject, two interesting experiences made recently in France may be given.

One tried, in November and December 1913, by the Roads and Bridges Department on the Canals of the Aire and the Neuffosse, between Bethune and the Fontinelles lift, at Arques, thus on a distance of 35 km. (22 miles) without any locks.

The width of the channel is only 10 m. (11 yds) with a nominal depth of 2 m. (2.2 yds) to 2 m. 20 (2.4 yds): but at a number of points the draught, on each side of the channel is considerably reduced by the deposits of mud.

At bridges and foot-bridges (there are 23 on this section) the width is reduced to 5 m. 10 (5.6 yds).

By reason of the especial difficulties that traction presented under such unfavourable conditions, it was necessary to attach the barges to long tow-ropes (50 to 80 m. between the barges, 100 to 120 m. between the first one and the tug) so as to give them every scope for good steering.

A small tug of about 60 HP. drew 5 loaded barges against the stream (6 or 7 in the opposite sense) at a speed of 2 km. (1 1/4 miles) per hour.

It may be said that this trial has given every satisfaction.

Another attempt was made by the « Compagnie de Halage du Nord-Est » on the canal lateral to the Aisne on the reach comprised between Bourg-et-Comin and Berry-au-Bac.

It is true that this reach presents particularly favourable conditions for towing by tugs.

Its length is 21 km. (13 miles). The width of the channel, with a normal depth of 2 m. 60 (8.7 ft), is 14 m. (15.4 yds). At the load-water-line this width is 24 m. (26.4 yds).

The current created, in the direction from Berry to Bourg, by the turbines installed at this latter point to feed the reach starting from Braye, a current of which the speed varies from 600 m. (660 yds) to 1 km. (1,100 yds) an hour, renders animal traction slow and onerous.

The irregularities and the obstruction caused by the insufficiency and the want of power of this method of traction, led the « Compagnie de Halage du Nord-Est » to have recourse to a mechanical method.

Some exact trials were made by the distinguished Chief of the working department of this Company, Mr. Berna, during August 1913.

The following are the principal facts and results :

The tug employed, 17 m. (18.7 yds) long, was supplied with a compound 100 HP engine, running at 180 revolutions.

Its draught at the stern was 1 m. 85 (6 ft) and the diameter of the screw 1 m. 40 (4 1/2 ft).

It towed 3 and 4 barges, carrying a useful load of 850 to 1140 tons at an effective speed of 3 to 3.5 km. (1 7/8 to 2.2 miles) against a current of 600 to 750 m. (660 to 825 yds) per hour.

The traction effort on the tug varied from 1.2 to 1.5 tons and the indicated power never exceeded 88 HP.

These trials, undertaken during a fairly long period, never brought to light any inconvenience.

Barges with tow-ropes about 55 yds long behaved best.

The journey which, with horses and at the price of the greatest efforts, demanded 20 hrs and more was currently made in 5 to 6.

The surge produced by the tug when towing, and even when not doing so, provided that the speed is not more than 7 or 8 km (4 3/8 or 5 miles) an hour, does not cause any dammage to the banks.

On the other hand the eddy from the screw washes away the bottom of the canal.

If there is no danger of leaking, a little dredging will be enough to remove the slime that settles on the surge beam.

The cost of this would be counter-balanced by the least care of the tow-path.

And after all, it is known by the experiences which were pursued in Germany by Professor Flamm, that it is possible to avoid any washing-away by fitting to the bottom of the rudder a horizontal plate of iron, bent slightly backwards, against which the eddies from the propeller break and are directed, by the rudder, towards the bottom.

Thus the only objection that we know of against towing by tugs on canals is done away with.

To sum up, in reaches which are long enough, (5 or 6 km. = 3 1/8 or 3 3/4 miles, for instance) and wide enough to allow of easy crossing, towing by tugs seems to be one of the most economical solutions that can be imagined, by reason of the absence of any fixed installation.

In order that the tug may not remain idle while the barges are being passed through a lock, the working should be done by reaches, the tug which brings a number of barges to a lock should return immediately with the boats from the next reach, which had been locked while she was making her journey to the lock.

One or two « courbes » (1) of horses, according to the intensity of the traffic, would be sufficient to deal with the manœuvring at the locks and the placing in position of the barges.

Breaking up of ice on Canals and Rivers.

Among the numerous causes of loss of time, enumerated above, from which navigation on canals suffers, there is one important one which has not yet been mentioned : It is obstruction by ice.

The stoppage thus provoked is all the longer because, by reason of the complete absence of current, the breaking up of the ice only commences some time after the thaw begins.

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(1) On the canals the horses always go by pairs and the « courbe » is composed of two animals.

In France, at any rate, the department of Roads and Bridges has only very rudimentary means at its disposal for breaking up the ice.

A simple ferry-boat, heavily ballasted, drawn by horses, is not always enough to obtain the complete liberation of the channel.

It was with the aim of hastening the reopening of navigation, on the canals as well as on the tributaries with locks of the Seine, that the writer of the present paper was led, on the initiative of a group of users of the said water-way, called « Syndicat de la Protection de la Navigation Hibernale », in 1908, to study an ice-plough easily placed at the bow of a tug.

On the 3rd of January 1909, the canal lateral to the Oise, between the Janville and Cluny locks, a total length of 34 km. (21 miles), covered with a sheet of ice about 12 cm. (4 4/5 ins.) thick, was opened up in less than 5 hours.

Navigation recommenced immediately after the passage of the plough. (1)

B. — NAVIGATION ON RIVERS.

Because of the existence of a current, the conditions of navigation, even on rivers with locks, are essentially different to the preceeding ones.

This is more especially the case when the transport is against the stream for then the speed and cost of traction play a very important part in the price of freight.

Boats for river traffic must be made finer otherwise towing becomes onerous and in consequence the cost of transport increases.

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(1) By reason of the mild winters that followed it was only later on that it was possible to again test the efficacity of the apparatus.

In the course of the winter 1913-1914 several ploughs broke up the ice with success on the tributaries and at the openings of locks between Rouen and Paris.

In February 1917, the Villette dock, at Paris, frozen to a depth of 0 m. 50 (1 ft 8 ins.) was freed in one morning.

The Navigation Companies of the Seine have now at their disposal about 10 of these machines which, in case of need, they place at the disposal of the Administration of Roads and Bridges

However, the influence of tonnage on the price of freight remaining, as on canals, of preponderating importance, this fineness should be moderate and suited to the river on which the boat is meant to navigate.

On the Seine, for instance, where the current is generally feeble (about 550 yds in summer) and only becomes strong (2 1/2 to 3 3/4 miles) at times of floods (now very frequent it is true), the fineness of the boat may be less than on the Rhone, where the current is always impetuous.

Navigation on the Seine between Rouen and Paris.

The tonnage on this route has taken, in recent times, considerable extension, as the table given below bears witness :

Tonnage of goods between Rouen and Conflans and vice-versa.

YEARS	Effective tonnage between Rouen and Conflans	Number of boats	Average tonnage of boats	Increase of tonnage with regard to 1902	REMARKS
	Tons		Tons	Per cent	
1902	1,725,405	7,398	233	—	
1904	2,164,316	9,126	237	+ 25	
1906	2,864,182	11,088	258	+ 66	
1908	3,014,500	10,130	297	+ 75	
1910	2,818,378	10,046	281	+ 63 (1)	(1) Floods stopped the navigation.
1912	3,465,997	12,042	288	+109	
1913	4,054,536	12,979	312	+135	

Until the last few years the transport of goods was almost entirely done by barges.

This means has become more and more insufficient as the tonnage has increased and it was necessary to have recourse to a type of boat offering less resistance to traction, otherwise a quantity of goods, that the barges could not carry, at the time of floods, would have been left at Rouen instead of being sent on to the centres of consumption, Paris and neighbourhood, on their arrival.

In summer when the current of the river is feeble a tug of average power tows 6 barges under acceptable conditions.

At the moment of floods this number has to be reduced to two and the time taken for the journey (150 miles) is increased by 40 to 50 % and more, by reason of the diminished length of the working days.

The effective work of the tug is thus considerably reduced and may fall to 20/100 of what it is in Summer.

Finer boats on the Seine.

It was under these conditions that we were personally led to studying and building boats which satisfied the double condition of carrying more while not needing a traction effort that was as considerable as that for barges.

For the last few years these boats have given complete satisfaction on the route between Rouen and Paris, and there are actually more than 100 running.

By reason of the needs and the exigencies of customers, there are 3 types carrying respectively, as full load, 380,575 and 750 tons.

It is to be noted that, as far as we are concerned, we have not thought it necessary to go beyond this last tonnage which seems to satisfy absolutely all needs.

But other enterprises have surpassed it considerably by having units of 1,400 and 1,500 tons built.

The scope of the present work does not allow of giving details concerning this finer material, for the rest they are not of great interest.

It will suffice to observe that the coefficients of displacement are 0.91 for the wooden boats of 380 and 575 tons, and respectively 0.803 and 0.838 for those of steel of 575 and 750 tons.

Results obtained by the use of finer boats.

The following table sums up the long trials that we made in order to render account of the value of these boats.

NAME OF BOAT	Type of boat	Number of trials	Useful load in tons	Total displacement in tons	Draught	Surface immerged at the midship-frame	RESISTANCE TO TRACTION AT A SPEED OF 2 METERS PER SECOND				Coefficient of displacement	Relation between the traction effort per ton of load compared with the barge « Vernon » for a speed of 2 km.
							Average total	Per ton of useful load	Per ton of displacement	Per sq metre of immerged section at the midship-frame		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	12)	(13)
			t	t	m	m	kg	kg	kg	kg		
Vernon	(1)	2	321.2	371	2.02	10.10	1.092	3.397	2.943	108.1	0.98	1.00
Toulousain	(2)	2	390.5	440	2.47	12.35	0.692	1.772	1.573	56.0	0.915	0 52
Abbevillois	(2)	9	309.0	409	2.34	11.70	0.686	1.911	1.677	58.6	0.915	0.56
Bourguignon	(3)	2	577.4	638	2.63	17.10	1.023	1.772	1.603	59.8	0.91	0.52
Béarnais	(3)	2	518.2	579	2.43	15.80	0.828	1.598	1.430	52.4	0.91	0.47
Provençal	(3)	4	526.0	587	2.445	15.89	0.817	1.553	1.392	51.4	0.91	0.46
Anglais	(4)	2	556.0	619	2.62	17.03	0.631	1.135	1.019	37.1	0.803	0.33
Italien	(4)	6	506.0	569	2.50	16.25	0.569	1.124	1.000	35.0	0.803	0.33
Australien	(5)	2	707.6	790	2.685	20.94	0.771	1.090	0.976	36.8	0.838	0.32
	Results obtained by M. De Mas.						Results obtained by M. De Mas.					
Dalila	(1)	»	»	342	1.81	9.05	1.462	»	4.275	161.6	0.99	»
Julie	(6)	»	»	240	1.36	6.83	475	»	1.979	69.5	0.97	»
Julie	(7)	»	»	279	1.43	8.51	865	»	3.100	101.6	0.95	»
Panama	(8)	»	»	283	1.42	7.99	407	»	1.438	50.9	0.904	»
Remesch	(9)	»	»	203	1.30	6.38	349	»	1.719	54.7	0.935	»

(1) Barge. — (2) Small wooden « chaland » (Barge). — (3) Large wooden « chaland ». — (4) 550 ton steel « chaland ». — (5) 700 ton steel « chaland ». — (6) Toue. — (7) Flute. — (8) Iron « chaland ». — (9) Prussian boat.

A barge « Vernon » of the ordinary type of to-day (called a « chaland » by bargemen) was taken for puposes of comparison.

The table gives besides a few figures obtained by Mr. de Mas, General Inspector, during the course of the memorable trials that he made.

The barge « Dalila », whose resistance to traction is greatly superior to that of the « Vernon », belongs to another type (called « Bateau de Canal »), a good carrying boat but very heavy and a type that is becoming rarer and rarer.

To sum up, and from a practical point of view this is the only result worth retaining, the making of boats finer reduces respectively, in the proportion of one half and one third, the effort necessary to tow a ton of useful load at the rate of 7.2 km. (4 1/2 miles) an hour, the comparison being made, we repeat it, with a relatively very light barge type « chaland ».

These conclusions, resulting from more or less theoretical trials, needed to be sanctioned by practical results.

The following observations corroborate them :

In summer, at a moment when the level of the river is not at low-water mark, two identical tugs, developping on an average 325 HP start from Rouen, one with six fine barges (« chalands ») representing together a useful tonnage of 2,842 tons, the other with five barges carrying altogether 1,792 tons, thus in favour of the former, a tonnage superior by 60 %. The first tug accomplished the journey of 107 miles between Rouen and Conflans, locking and loss of time included, in 51 h. 45 min., and the second in 60 h. 30 min., thus an economy of working hours of 17 %.

In winter, at the period of floods, the barriers being effaced, two similar tugs, whose average power was 225 HP, accomplished the same journey under the following conditions :

One tows three fine barges, carrying a useful load of 1,083 tons. The time necessary for the journey is 50 1/2 working hours.

The other tows only two barges with 701 tons and takes 56 hours for the journey.

Thus, in favour of the former, an advantage of 54 % in tonnage and 11 % in working hours.

Towing dues.

Thanks to the fine boats, of which the number increases without ceasing, and which tend to replace the barge completely; thanks also, it must be admitted, to active competition, the towing dues between Rouen and Paris have been considerably reduced during the last few years.

What is more this reduction is more important in reality than in appearance, and this by reason of its mode of application.

In effect it is customary to reduce by 50 % the due on every ton above 300.

So that the tonnage of a barge which, by reason of the depth could carry 360 tons on the Seine will only be reckoned as 330 tons.

The difference is not great but it has its importance when it is a matter of a large barge of 700 tons; the whole due will only be applied to $300 + \frac{700-300}{2} = 500$ tons.

These dues were 0.009 fr. in winter and 0.005 fr. in summer per kilometric ton.

With the above indicated reduction, they correspond respectively to 0.0083 fr. in winter and 0.0046 in summer, for the load of a barge, which was almost the only boat used then.

At the present time, by reason of particular circumstances in which unreasoning competition has more influence than economical considerations, the dues descend to a rate which, with the above mentioned reduction and for a 700 ton barge, may reach about 0.0035 to 0.004 fr. at the time when the barriers are lowered and towing exceedingly difficult and 0.0014 fr. to 0.0018 fr. in Summer, when the circumstances for traction are the least difficult.

To sum up, in a few years the cost of towing per kilometric ton has been reduced by more than 50 % in winter and by 60 to 70 % in Summer.

The efficiency of a tug.

Can it be conceived that these reductions, but little justified, it must be said, by the charges of every nature (considerable increase in the price of fuel and of labour) that burden towing, will continue in the future?

This is a question that it would be rash to answer.

But, unless one imagines a complete overturning in this mode of traction, it seems very improbable that any new decreases may be looked for.

The towing dues remunerate exactly, in fact, the working-expenses and in particular the cost of fuel, the price of which rises continuously.

If one agrees to measure the commercial efficiency of the tug by the relation between the product of the effort on the tow-rope by the speed (measured at the bank) and the indicated power of the machine, we shall see that this relation, which varies essentially with the current, is feeble enough.

It quite seems that, outside of every theoretical consideration, this figure perfectly characterises the relations between the receipts and the expenses.

In practice, the load of the tug is, as far as possible, appropriated to the state of the stream, for there exists certainly a « best » speed, which it is however difficult to define, and which it is advisable to observe.

If it be exceeded, the work is absorbed by a useless and costly speed; if it be not reached the productive and remunerative efficiency declines progressively to zero, in the case where the tug just holds the current.

In spite of all the care that may be given to the composition of the convoy, it will happen that, at the time of floods, the tug will meet, in narrow passages or under bridges, a more violent current than elsewhere and, in these points, its useful effect, will fall perhaps to 9 % and even less, as is indicated in the table hereafter which sums up the trials we made.

Commercial efficiency of a tug against the current.

Composition of the convoy (1)	Total load of the convoy (2)	Speed of the current per second (3)	Speed of the current per hour (4)	Speed of the convoy with reference to the bank per second (5)	Speed of the convoy with reference to the bank per hour (6)	Speed of the convoy with reference to the water per second (7)	Speed of the convoy with reference to the water per hour (8)	Indicated power of the tug (9)	Traction efforts on the tow-rope (10)	Useful work $\frac{(10) \times (5)}{75}$ (11)	Commercial efficiency $\frac{(11)}{9}$ (12)
	Tons	M.	Km.	M.	Km.	M.	Km.	H.P. of 75 K.g.m.	Kil	H.P. of 75 K.g.m.	
4 barges	1266	1.430	5.148	0.610	2.196	2.040	7.344	181.41	2047	16.65	0.09
	1266	1.300	4.680	0.780	2.808	2.080	7.488	219.72	2696	28.04	0.13
	916	1.239	4.460	0.778	2.801	2.017	7.261	185.75	2399	24.69	0.13
	1266	1.150	4.140	0.740	2.664	1.890	6.804	192.49	2544	25.10	0.13
	916	1.029	3.704	1.030	3.708	2.059	7.412	219.18	2657	36.49	0.17
	1266	0.810	2.916	0.880	3.168	1.690	6.084	210.46	2771	32.52	0.15
	916	»	»	1.309	4.712	»	»	239.10	3050	53.23	0.22
	916	»	»	1.495	5.382	»	»	230.47	2862	57.04	0.24
	916	0.601	2.164	1.553	5.591	2.154	7.754	225.72	2874	59.51	0.26
	916	0.379	1.364	1.692	6.091	2.071	7.456	203.25	2540	57.31	0.28

To sum up, under normal conditions and with a load in proportion to the power of the tug, what we call the commercial efficiency on an average varies between 25 and 20 % and may frequently go below this.

With the sole idea of finishing with the question of towing by tugs we give hereafter some results of trials at a fixed point with reference to the traction effort compared with the indicated HP.

Traction effort in kilogrammes per indicated HP.

NAME OF THE TUG	Indicated H. P. (1)	Number of revolutions per min. (2)	Traction efforts on the tow-rope (3)	Traction per indicated HP. $\frac{(3)}{(1)}$ (4)
	H. P.		Kilogrammes	Kilogrammes
Raymond	104.5	174	1700	16.3
Guêpe n° 35 . . .	131	180	2000	15.3
» n° 50 . . .	235	174.5	3220	13.7
» n° 26 . . .	247.41	194	3505	14.17
Conflans	249.45	164	3600	14.43
Guêpe n° 16 . . .	306.7	141	3691	12.03
» n° 15 . . .	356.81	146	4180	11.72

Towing by a submerged chain.

This method of traction on rivers is too well known for there to be any interest in analysing its good and bad qualities.

However it may be useful to draw attention to the important advantage that it offers, for towing, when it is a question of hauling the boats against the stream.

What we called above the commercial efficiency of the tug takes, for the tow-boat, a much greater value, as the table below shows clearly.

Commercial efficiency of a tow-boat against the current.

NAME OF THE TOW-BOAT	Number of boats in the convoy	Total load of the boats	Speed of current		Speed of the convoy with regard to the bank		Speed of the convoy with regard to the water		Indicated HP of the tow-boat	Traction effort on the tow-line	Useful effect $\frac{(11) \times (16)}{(75)}$	Relation (12) (10)
			per second	per hour	per second	per hour	per second	per hour				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		Tons	Metres	Kilom.	Metres	Kilom.	Metres	Kilom.	H. P. of 75 k.g m.	Kilogs	H.P. of 75 k.g.m.	
Charleroi	9	3058	0.303	1.091	1.274	4.586	1.577	5.677	103.78	3.850	65.40	0.63
Id.	9	3058	0.303	1.091	1.250	4.500	1.553	5.591	98.04	3.850	64.16	0.65
Id.	9	3058	0.196	0.706	1.312	4.723	1.508	5.429	113.39	4.300	75.22	0.66
Id.	9	3058	0.175	0.603	1.256	4.522	1.431	5.152	103.68	3.800	63.64	0.61
Oise	3	870	0.256	0.922	1.666	5.998	1.922	6.919	78.21	2.100	46.64	0.60
Id.	3	870	0.222	0.799	1.723	6.203	1.945	7.002	65.52	1.750	40.23	0.61
Id.	8	2213	0.196	0.706	1.119	4.028	1.315	4.734	64.02	2.450	36.55	0.58
Id.	8	2213	0.181	0.652	1.235	4.446	1.416	5.098	72.29	2.800	46.07	0.63
Id.	8	2213	0.151	0.544	1.274	4.586	1.425	5.130	83.30	3.000	50.96	0.61
Toueur n° 1	7	1952	0.181	0.652	1.062	3.823	1.243	4.475	44.04	1.800	25.49	0.58
Id.	7	1952	0.166	0.598	1.158	4.169	1.324	4.766	44.63	1.700	26.25	0.59
Id.	6	1695	0.256	0.922	1.111	4.000	1.367	4.921	47.55	1.760	26.07	0.55

Acceleration of transports on rivers.

The price of transport is above all a question of the utilisation of the material.

Against the current, a best speed exists, which must be kept to, under pain of increasing the cost of traction and, in consequence, that of the transport.

The causes of loss of time are here less numerous than on canals.

In the reaches, the only frequent ones are caused by the want of zeal on the part of the staff, and this cannot be remedied by any administrative regulations.

At locks, improved mechanical means are of a nature to cause time to be gained.

Such is the case for those of « Port à l'Anglais » on the Seine.

A considerable traffic of 8,600,000 tons necessitated the intense utilization of mechanical means.

The firm Hillairet and Huguet, of Paris, was entrusted with the work of studying and applying the electric working of the gates, sluices and capstans.

The really remarkable installation, from every point of view, which the scope of the present work does not allow of describing, is similar to that of Gœulzin.

The results obtained are very appreciable :

The total length of time necessary to pass 8 boats is reduced from 40 to 27 minutes (1).

The electrical controls have allowed of reducing the staff, so that the economy realised from this alone nearly compensates for the cost of upkeep of the installation.

But another cause of loss of time, more important than that due to the more or less lengthy manœuvring of the gates and sluices, is imputable to the slowness of the entrances and exits of the convoys. In order to empty a lock, the tug proceeds very slowly so as to stretch all the tow-ropes successively and it is only when the last boat is under weigh that it acquires, little by little, the normal speed.

Now, at the departure, the boats of a convoy are separated by intervals of about 33 yds., except the first, the tow-rope of which is about 70 yds or 80 yds long.

At starting the barge-owner allows his tow-rope to slide in order to avoid the risk of a shock which might tear out the bollard.

It follows that at the end of the journey, after 8 or 10 similar manœuvres, the tow-rope has lengthened and that the length of the convoy has sensibly increased, to the extent of 30 or even 40 %.

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(1) Taken from a memorandum by Mr Imbs, Engineer of Roads and Bridges.

The exit being performed at the rate of 1 1/8 to 1 1/4 miles per hour at the outside, one can judge what time may be necessary to empty a chamber containing frequently, as at Bougival, 14 barges and 3 tugs.

The developed length of these 3 convoys reaches 1,500 m. (7 1/2 furlongs) and at a speed of 1 1/4 miles per hour demands 45 minutes.

Timing by the watch will verify this.

By shortening the tow-ropes in each lock, 10 minutes could certainly be gained on the time of exit, thus more than by all mechanical improvements.

A regulation would perhaps intervene efficaciously.

In any case it would have to reckon with the inertia of the staff, on whom it would have to impose an increase of work which would not be easily accepted (1).

Navigation on the Rhone.

By reason of the violence of the current, the Rhone presents, for navigation, difficulties which are incomparably greater than on any other river.

Its descent is, indeed, exceedingly pronounced.

The low-water mark is at Lyons, at an altitude of 158 m. 52 (520 ft.) above the level of the sea, from which this town is only 200 miles distant by river.

Now to find the same altitude it is necessary to go up :

The Rhine, beyond Strasbourg, 480 miles from the sea; the Elbe, 510 miles; the Danube, 1,100 miles (2).

As for the average kilometric descent, measured on short lengths of from 165 yds, to 440 yds, it reaches, in certain passages, 11.4 to 13.2 ft.

The difficulties due to the speed of the current, are aggravated still further by the essentially variable state of the river. The depth in some points being reduced to 4.6 ft, in spite of the important improvements made between Lyons and Arles.

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(1) Since this paper was written, a tendency to sensibly shorten the tow-ropes has been manifested. On the Seine now it is not rare to see boats which are separated by not more than 10 meters.

(2) An extract from a communication by Mr Collard, Chief Engineer of Roads and Bridges.

It should be added, however, that before these improvements the draught, in places, was as little as 1.6 or 1.9 ft.

Under such circumstances only specially planned material could allow of undertaking towing against the stream.

This materal was found by the « Compagnie Lyonnaise de Navigation et de Remorquage », whose initiative cannot be too highly praised.

For the time-being it consists of 3 tugs and 30 barks.

It was planned by the house of Escher Wyss and the machines built in their works at Zurich.

The hulls of the tugs and barks were set up in France.

New material in use on the Rhone.

Tugs.

They are with paddle-wheels. The hull has a total length of 72 m. (236.26 ft.) and a width of 6.6 m. (21.65 ft.) at the midship-beam, and of 18 m. 10 (59.4 ft.) outside the paddle-boxes.

The height in the middle is 3 m. 10 (10.2 ft.)

The draught is 1 m. 05 (3.5 ft.) with 20 tons of coal and 1 m. 15 (3.77 ft.) with 70 tons.

The machine, compound, is slightly inclined on the horizontal and the cranks drive directly the shaft of the wheels.

The diameters of the cylinders are respectively 780 and 1,360 m.m. (30.7 and 50.3 ins.) and the common length of stroke 1,800 m.m. (70.9 ins.).

Steam is produced by 4 marine boilers, 2 m. 941 (9.65 ft.) in diameter placed 2 before and 2 behind the machine.

The total heating surface is 420 m^2 (4520 sq. ft.).

They are supplied with superheaters of 100 m^2 (107.6 sq. ft.).

The normal force of the machine is 1000 HP., but this can be doubled by letting in live steam at the large cylinder.

A special disposition has been provided for the case when the tug is unable, with its load, to pass certain rapids.

A shore, across the hull near the bow, is then liberated and buries itself in the bed of the river. The tug thus stopped in full channel can haul the convoy by means of strong steam-winches.

This disposition has, however, never yet been used.

Barks.

Their principal dimensions are as follows :

Length 65 m. (213 ft.), width 7 m. 9 (26 ft.); height at the centre 2 m. 50 (8.2 ft.).

They can carry 625 tons with a draught of 1 m. 80 (5.9 ft.).

The coefficient of displacement is 0 m. 83 (2.7 ft.).

They weigh 140 tons empty.

Results obtained.

The builder had guaranteed that a tug could draw, from Arles to Lyons, a total load of 2,500 tons divided up among 4 barks at a speed of 4 km. (2 1/2 miles) per hour with reference to the bank.

In the region of the rapids, from Pont-St-Esprit to Tournon, over a distance of 101 km. (63 miles), the convoy has to be divided into two equal parts, and two barks, carrying together 1,250 tons, should be towed at a speed of 4.5 km. (2.8 miles).

During the first trial, which took place in April 1914, 3 barks carrying altogether 1420 tons were towed, without breaking up the load, from Beaucaire to Lyons (distance 268 km. = 167 miles) in 48 travelling hours, i. e. at a speed of 5.6 km. (3.5 miles).

The admission of steam to the small cylinder which might go to 70 %, was generally only 30 % and 40 % in the region of the rapids.

Up to the present time recourse has never been had to the admission of steam to the large cylinder : that of 70 % to the small one has always been enough to obtain the necessary power to pass through the most difficult passages.

The descent of three barks by towing, which, from what the pilots say, should be impossible, is easily managed.

Price of transport.

The enterprise, of which we have just given the outlines, is too recent for it to be possible to exactly fix the prices that may be charged.

It is however reckoned that when in full activity and if the descending traffic, consisting of principally building materials, reaches the half of the mounting (corn, wines, phosphates, coal) the freight will not sensibly exceed 0.01 fr. the kilometric ton.

This is, it must be repeated, only a forecast.

In any case the prices charged will be lower than those actually applied by the railway.

They will allow of the transport of goods, especially building materials, which up to the present could not be exported outside of the centre of production and will create, there is no doubt about it, an important current of traffic.

SUMMING UP. — CONCLUSIONS.

In short, it results from the present study that, from an economical point of view, the element that plays a primordial role in the lowering of the price of freight is the carrying capacity of the boat, no matter whether it be on rivers or on canals.

Unfortunately this solution is inapplicable to the existing artificial waterways and we have seen that, even for a canal under construction (Canal du Nord), it was not thought necessary to adopt it.

However it would be possible, and this without exaggerated expense, to slightly increase the depth of certain waterways, were it only by 8 inches. This increase, however small it might be, would not be without influence on the price of freight.

Though this affirmation may appear paradoxical, the barge, with its tubby form, is an instrument very well adopted for transport on canals. The making of it finer, which would diminish its carrying capacity, would only increase the cost of freight.

On rivers, even those canalised, it is quite another thing, the material should be finer and adapted to the route it has to serve and to the demands of the customers.

The acceleration of the transport, which has for immediate consequence a better utilisation of the material, is, in any case, a means of reaching the desired goal.

But, to arrive at this, one should keep in view less the increase of speed itself, which is very onerous as we have seen, than the suppression, or at least the diminution, of loss of time owing to crowding, waiting at locks and insufficiency of the means of traction, etc.

On the canals, well thought-out regulations judiciously applied by zealous and intelligent agents, would go far in obliging bargemen to continue their route without injustifiable stops. Obstruction in the reaches would thus be avoided.

On rivers the need of such a regulation does not in any way appear necessary.

Organisation of the traction, in proportion to the needs, would lead to the same goal.

Monopoly is necessary in many cases, especially when large capital is needed to organise the enterprise, but it should not be granted to the State, which should keep to its role of controller.

The mechanical solutions examined in the course of this study will satisfy all needs.

Electric towing on rails will be employed where there is heavy traffic; cable traction can render appreciable services when the reaches are short and the canals divided up into a number of sections; the motor-tractor, with no expenses for installation, will find its application for middling traffic or when the distances are long.

Towing by tug will constitute, it cannot be too often repeated, an efficacious manner, most certainly economical and which could be utilized in a number of cases, without it being necessary for the canal to afford particularly favorable conditions.

The losses of time at locks will be lessened by the good arrangement of the latter and by the improvement of the mechanical appliances.

The Gœulzin lock is a model to be imitated.

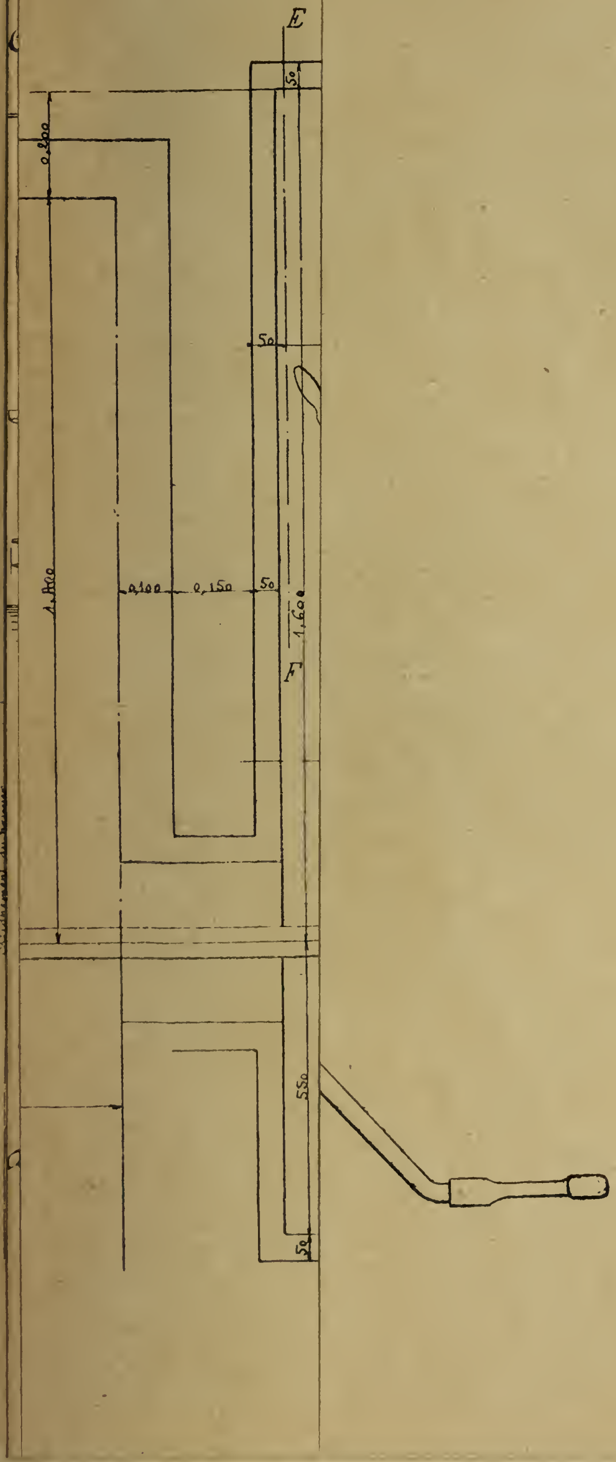
The decrease in the number of locks is also to be recommended for the same object.

Thanks to the successful arrangements conceived by the « Société des Grands Travaux » of Marseilles for the type studied by the Company, it may be said that the fall is no longer limited by considerations of a technical order.

Regulations tending to obtain more rapidity in the manœuvres on entering and leaving the locks on rivers, as has been explained, would have good effects.

But it must not be lost to sight that this could only be done at the price of extra work and care, which it is always difficult to impose on and have accepted by a staff naturally enough indolent.

Translated by : E. Leeds, 42, rue de l'Enseignement, Brussels.

E
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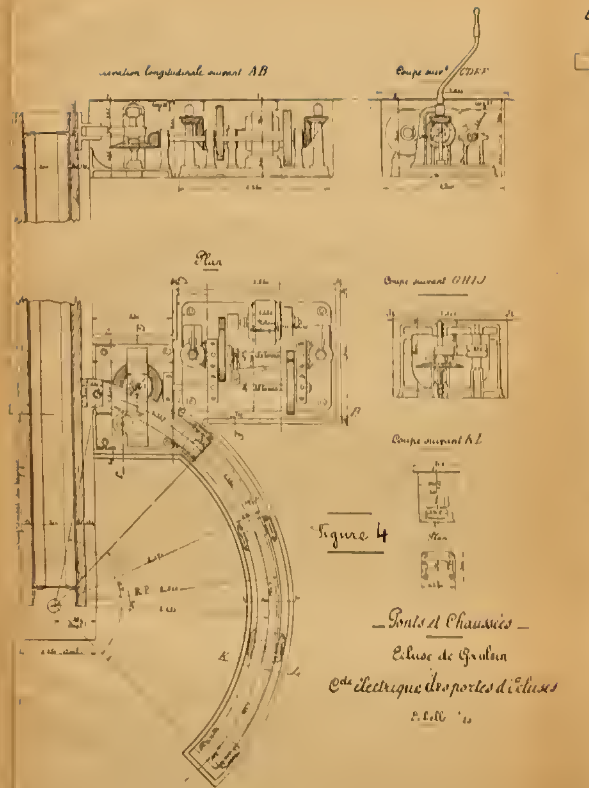


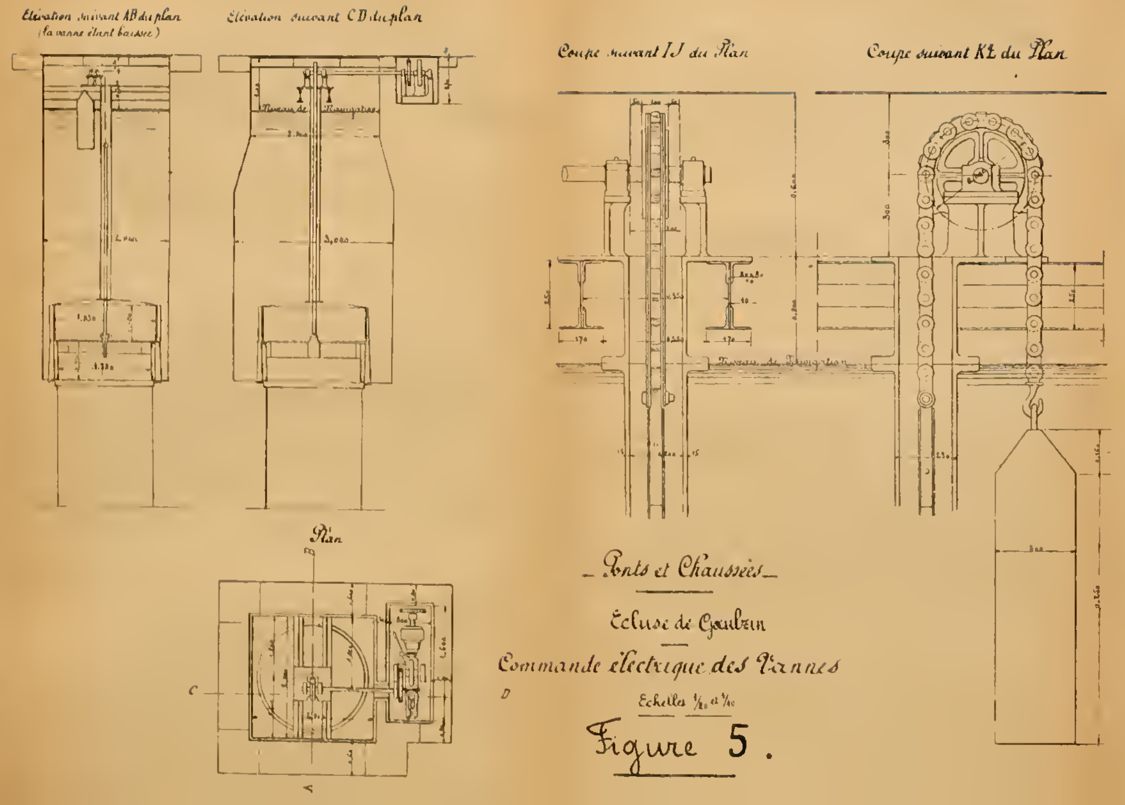
Figure 4

Ponts et Chaussées

Écluse de Gaulzin

Cᵈᵉ électrique des portes d'écluses

Echelle 1/20



Ponts et Chaussées

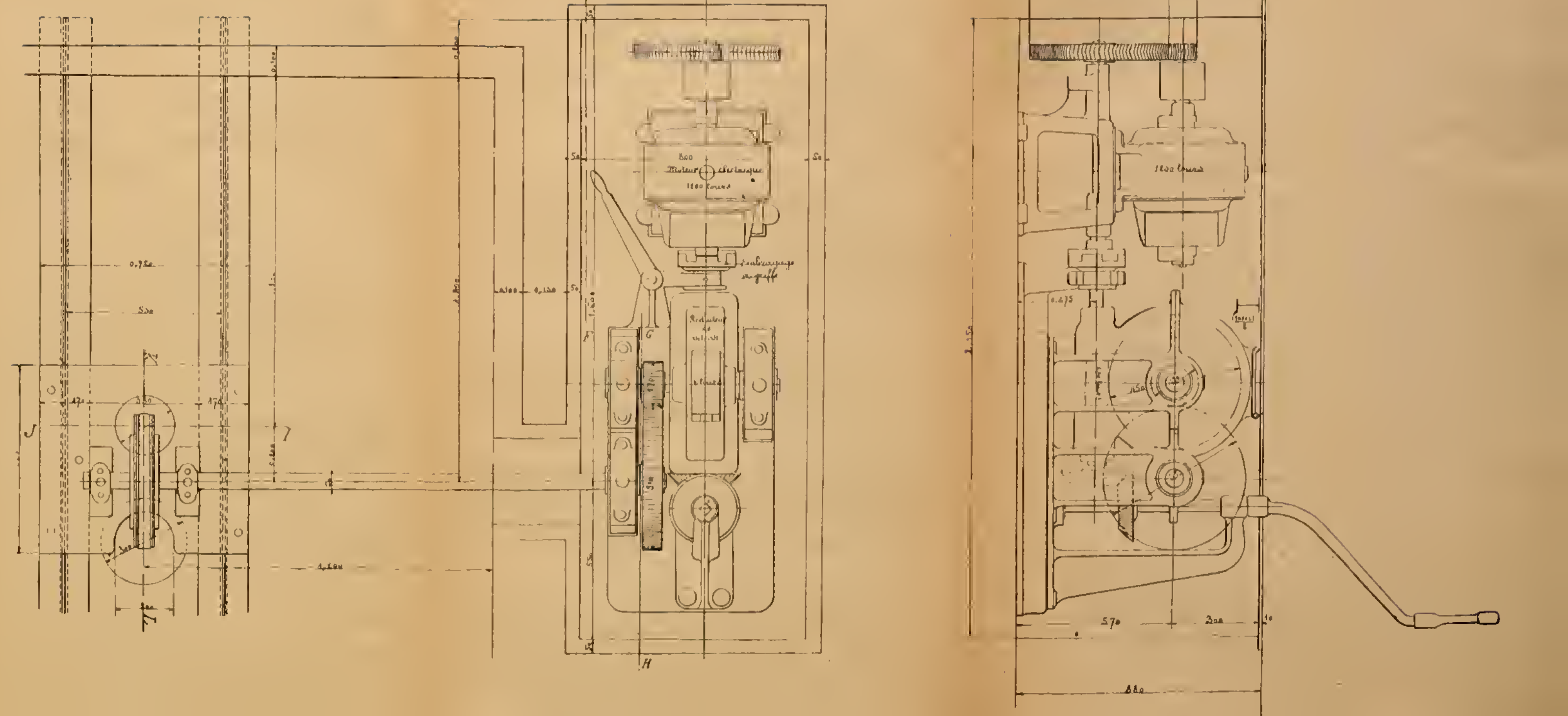
Écluse de Gaulzin

Commande électrique des Vannes

Echelles 1/20 et 1/10

Figure 5.

Figure 5 (suite)



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